this band across the cell is nearly of the ground color of the wing; a subapical dark patch rests on the costa in four equidistant dark brown dots; a dark spot between the end of the cell and the outer border very dark at the beginning extends obliquely down to the outer border a little above the anal angle. Ground color of fore wing with numerous cross streaks of a brighter yellowish color. Fringes concolorous with the ground color of the wing. Hind wings light gray with darker reticularions. Underside of all the wings lighter than above and faintly reproducing the markings of the upper side. Expanse of wings, 12 mm.

Described from one male specimen in the National Museum, from Florida, bred from *Iva imbricata*. Type no. 5416 U. S. National Museum.

NOTES ON SOME DIGGER BEES.—II.

By JOHN B. SMITH, Sc.D.

(PLATES III–V.)

Augochlora humeralis *Patton.*

The first introduction to this species came April 4, 1898, when digging out plaster casts of spider burrows. At that time Mr. Brakeley ran across occasional vertical burrows, filled at the top an inch or so, but open below that and extending down fully three feet. Beyond that they were lost and were looked upon as unusually deep old *Colletes* diggings.

April 17th, an area 18 x 16 x 23 inches was cleared of pine needles, lichens, moss and other surface débris, and about an inch and a half of sand was skived off cleanly, with a large sharp trowel. In this area 13 round holes about one-fourth of an inch in diameter were now exposed. From one of them a bee came up and was captured. It proved to be *Augochlora humeralis*, Mr. Fox and Mr. Ashmead separately determining the species for me.

Plaster was now poured into several of these holes and to Mr. Brakeley's astonishment the first opening required four fluid ounces to fill. The others required yet more, until in one case nine ounces were needed to bring the mixture to the surface.

April 18th, digging began by making a trench before the area of casts, and working down an old burrow, the trench was deepened from time to time until it was fully four feet down. In the first cast a bee was imbedded 23 inches from the top, there was a totally different

arrangement of laterals from what had been noted in *Colletes*, and below the end of the cast, 41 inches from the surface, the hole yet went down: in other words the plaster had set before it reached the bottom. Other casts ran down 47¾ and 50½ inches, respectively, and at the bottom of the holes bees were found.

April 19th it rained, but on the 20th digging was renewed and one burrow was followed down 58 inches. Two bees were found in the bottom of one of these holes. Additional casts were made and were dug out from time to time, until well along in May, and at this time no two casts were alike. There was always the deep vertical extending down from forty-five to sixty inches. Beginning about six or eight inches from the top, lateral burrows might be expected, running at right angles an inch or two and then broadening out into a circular chamber about three-sixteenth inch in height, variable in diameter. From this chamber a variable number of verticals extended down a variable distance—sometimes only half an inch, more generally an inch, and almost always one or two were much deeper. Occasionally one of these verticals was extended down several inches, and it might even run off diagonally; though this was rare. So we found a few cases where the circular chamber was omitted and there was an irregular branching off from the lateral. There seemed neither rhyme nor reason in the differences and we were totally unable to find any traces of bees having developed anywhere in the burrows or the cells connected with them. So the number of laterals and cell clusters varied. Usually there were two; not infrequently there were three and rarely there was a fourth. Below 18 inches we never expected to find cell clusters; but sometimes there were irregular chambers forming little fingers in the casts, which might be found at almost any depth. The longest burrow measured extended 64 inches down; through a layer of sand, through a soft yellow clay into a stratum of hard red clay intermixed with iron, through this clay and through an eight-inch layer of sea sand it went through clay and hard gravel to water-bearing sand beneath. In one case eight bees were found piled one above the other nearly five feet under ground. When brought to the surface they were torpid and did not resent handling; but they became active very quickly in the bright sunlight and started flight when allowed to do so.

Of one thing we were of course certain: all these burrows had been made in 1897; but why were so many bees in one home, and why was there no trace of breeding? All the specimens were females,

and it did not seem reasonable to consider them as the brood that had been born in the system where they were found. There were too many complicated burrows with only a single bee, to make this probable.

May 13th I reached Lahaway to find a "bee mine" well established. It was six feet deep, with three perpendicular faces, the fourth side sloped for convenience in getting out. The process was, first clear a space in front of one of the perpendicular faces, usually about 18 inches square, by cutting off with a large trowel two inches of top surface. So full of holes was the ground here that anywhere from six to a dozen openings would be exposed in this area and of these three or four would be plaster filled. Usually 24 hours were allowed for the plaster to set; but sometimes casts made in the morning were taken out that same afternoon. Though every hole was not plastered, yet every one on the way to the casts was investigated. With a broad trowel the sandy face of the pit was sliced back until a perpendicular was reached: then a small, sharp trowel came into service to follow it carefully down, so as to expose all laterals and cell clusters. These in turn were investigated by a thin palette knife, so that we had clearly before us the whole digging record. Perpendiculars were rarely followed below two feet, because experience had taught us that no laterals or cell clusters were to be expected below that point. Unless we wanted bees, the end of the burrow was neglected.

A notable fact in comparison with the diggings of *Colletes compacta* was that those of the *Augochlora* were perfectly clean and open to the bottom, though covered with sand above. Not a trace of top sand was ever found at the bottom of the tube, where care had been taken to prevent its entrace from our own operations.

When a cast was approached within three inches, the small trowel was carefully used to reach the perpendicular, for we could never tell to which side a cell cluster would be found. From the top down the knife was used to bare the white cast, small slices only being made downward until the direction of the first lateral was discovered. If it ran to either side, matters were easy, for the cluster could be left untouched and the perpendicular followed down until the next cluster was located. When none was discovered at twelve inches from the top we felt very certain that it went off backward, which was also a satisfactory condition. Where a large cluster projected straight out forward matters were more troublesome for a support must be left for

this cluster from the side or below, otherwise it would break by its own weight and fall into the pit. This actually happened more than once. Of course as the pit filled from the sand scraped off its side, it was shovelled out from time to time to afford working room. Finally, when the plaster-filled tube was laid bare for its full length, arrangements could be made to take it out; which was a decidedly ticklish task. As the sand was moist, the cast naturally could not dry out completely nor the plaster set hard. It had a chalky appearance and feeling, and snapped in the most unexpected places in the most disconcerting manner. I have bared a perfect cast, lifted it out carefully and held it safe upright; but attempting to incline it so as to rest against a sunny slope, the whole thing collapsed, breaking into many pieces—to the great damage of my soul's weal, unless the recording angel kindly closed his or her ears temporarily. After a number of similar mishaps we decided to take the matter into our own hands, make no attempt to get perfect casts, but break them where we judged most desirable. Usually, therefore, the perpendicular was broken about six inches below the lower cluster and this left us anywhere from 20 to 30 inches of one-fourth inch pipe stem which could be laid down on the warm sand to dry out. The second break was usually made below the first cell cluster and after that it depended on circumstances. A reference to Plate IV, Figs. 16 and 17, will show the general appearance of the casts secured at this time and also the difficulty of securing a structure like this in one piece. Of course all the parts of one cast were carefully kept together and usually notes were made at the time, detailing the number of clusters, etc.

All the work done by Mr. Brakeley was elaborately noted. Every cast had a stick bearing a number and the quantity in ounces of plaster that had been poured in. This was useful as indicating a simple or a complicated system and was to some extent a guide in the digging operations. After an hour in the hot sun or dry sand, the casts were much more safely handled and much lighter. They were then laid carefully into a box especially made for that purpose and carried to the house.

Incidentally, it may be noted that the bee mines were from one-fourth to one-half miles away from the house and that everything, including the water, had to be carried out and back again. What with graduates, plaster, jars and other paraphernalia for digging, this made quite a load.

Arrived at the house the casts were laid out on boards, each series by itself, with its stick and head mark, and in the evening they were dry enough and hard enough to clean. Of course the round, simple perpendiculars could be easily cleared of the adherent sand by a stiff brush; but the cell clusters were usually a mass of sand and clay, and it was utterly impossible to tell what would come forth out of the lump. Dissecting needles and small brushes came into play here, and it was sometimes close to midnight before a day's field work would be finally laid out so as to show a proper record. When working alone, Mr. Brakeley made full notes of all that was done and seen and these notes, which gave as clear a picture as personal observation could have done, were sent me with the casts.

The first blue bee was noticed by Mr. Brakeley, May 1st, on flowers and thereafter an occasional specimen was seen. After a day or two of pleasant weather, May 14th proved one of those hot, sunny spring days that seem to have an electric power to start into activity all living creatures. This day terminated the hibernating period of *Augochlora* and sent them out among the flowers with a rush. The air was full of life, and bees were hovering over the sand in every direction.

Now it might be supposed that, having spent several months underground, the insects would enjoy themselves a trifle in the sunshine, and would assume family cares only after due deliberation, first clearing up and restoring their winter quarters into summer freshness; but being ladies, they did nothing of the kind. Hardly taking time for a full meal, each individual began at once to dig a new burrow, disappearing beneath the surface in a moment and indicating progress by the gradual forcing up of a little heap of sand. It is a fact that not one of the bees returned to the hibernating burrow and, despite the fact that the ground was fairly riddled with available perpendiculars from which new laterals could be driven, not one was so used. For every bee there was a new burrow. Their method was to fly restlessly here and there over the sand, hover for a few moments at one point, then at another and, finally as by a sudden resolve, drop to the surface and disappear. It was all done in a moment and a brilliant metallic greenish or bluish bee, seemed changed into a little heaving mound of sand. Then even this motion stopped for a few moments until a sudden heave forced out a little lump of sand, and the new burrow was fairly begun. At this time the digging is done chiefly with the fore-legs which loosen the sand and force it back a little.

Then the bee pushes forward, turns a complete sumersault at the extreme end of the burrow and with its head forces the sand to the surface.

The front leg of *Augochlora humeralis* is shown at Plate III, Fig. 1, and, as compared with the middle and hind legs (Figs. 3 and 5), differs by the lack of hair or other apparent vestiture. There is no distinctive digging structure; but the sand in which they work is generally soft and when obstacles are encountered the mandibles (Fig. 10) are brought in to assist. Femur and tibia are of almost equal size and very powerful. Before the end of the tibia is an articulated spur or process, toothed and forming a cover to a notch in the first tarsal joint. This is, of course, the antenna cleaner, and it is shown, more enlarged, at Fig. 2. The claws at the end of the fore tarsus are different from those on the other feet in that they are longer, more flattened, and inclosed for more than half their length in a membraneous sheath, leaving only the teeth projecting. Whether the claws can be completely withdrawn within this sheath, I do not know.

May 15th was an unpleasant, rainy day on which no bees were flying; but the 16th was again pleasant and on this day the first cast was made by Mr. Brakeley of one of the new burrows on a field where the bees were seen earliest. It was observed, first of all, before the casts were made, that the mounds were never open on the surface as in *Colletes*. That active work was going on could be seen by the increase in the size of the mound and the difference in the color of the sand and clay brought up; but all the work seemed to be done at night. During the day everything remained undisturbed; but next morning every mound showed fresh, moist, colored sand or clay, showing just where the insect had reached in its digging. As a matter of fact the mounds never increased very much in size. The hot sun of midday day dried them to a powder and any little breeze over the surface carried off a portion to be spread evenly over the surrounding surface; a rain levelled the whole to the surface.

The first cast was only 12 inches deep, but developed a new feature: the insects do not start at the top and go straight down! To make the cast the sand was cleared out of the center of the mound until a clean opening was obtained. The resulting cast was like Fig. 18 above the first cell cluster. It proved from this and other casts and diggings, that at first the bee digs diagonally a distance of three or four inches, to get about an inch and a half below the surface; then

she digs down vertically and runs the vertical up to the surface. But the opening to this vertical she keeps carefully closed so that not a sign of it appears to casual view. Furthermore, in almost every case the perpendicular comes up under some bit of natural protection—lichen, moss, grass tuft or anything else in fact. The object of the hovering search by the bees is now apparent ; they are seeking some place that affords a natural protection to the real entrance to the nest and the surface mound does not indicate this entrance within four inches in any direction. Plate IV, Fig. 19, shows a diagrammatic section of the entrance to the burrow. It is obvious that the perpendicular might be fully eight inches from its present location by removal to the exactly opposite side of the mound ; therefore the surface mound does not indicate within 6 or 8 inches the real entrance to the burrow. At first the casts were made through the oblique entrance ; but when it was found that the habit was uniform and that obstructions in the oblique arm often interfered with casting, it was decided to hunt up the perpendicular and cast into that. This was not so difficult after a time, for as soon as a little careful dissecting with the palette knife showed the direction of the perpendicular, one could be sure of finding it under the nearest natural shelter. There was always a plug closing this opening except when the bee was out seeking stock for its cells. Therefore it became easy in time to ascertain whether the owner was or was not at home. If we found everything tightly closed, we could take it for granted that the bee was at home ; but was not at all disposed so receive company. Frequently we dropped a little pebble or a pinch of surface sand into the opening and awaited events. In a very few moments the owner appeared at the surface, rarely bringing out more than half her body, looked wildly around in every direction, tried the edges of the burrow with her antennæ and then disappeared from view—only for a few seconds however. In an incredibly short time she re-appeared bearing a load of clay which she slapped into place at one edge and dived down for more. In two or three loads she had enough to completely shut the door. At first the discolored fresh clay was rather prominent ; but in a short time the sun or drying wind had lessened the contrast so that it did not attract attention.

Sometimes we found the door open, but not widely. That is, though the gallery was fully one-fourth inch in diameter, the opening through which the bee came out was not much if any more than half that, just large enough for the insect to get in and out.

The method of digging is interesting and was studied on a number of examples confined in glass tubes. The fore legs were used to scrape up material which was made into a lump clasped between the abdomen, breast and middle and hind femora. Then the insect crawled up actively but awkwardly, moving middle and hind legs as little as possible and confining the motion to the tibiæ and tarsi. Arrived at the surface or dumping ground the load was deposited in place by turning a complete sumersault and then diving down into the burrow head first. When it was a matter of closing the opening, the upper surface of the abdomen was used to press each load into place, but everything was done so rapidly that it all seemed part of one motion.

The bee is intensely and nervously active at all times when observed. It is never quiet a moment, but bustles about as if every second counted for much. Antennæ, legs and palpi are always in motion, whether in the burrow or on a flower, gathering pollen. It gives the impression of nervous haste, yet the haste seems well directed and effective, no false moves or motions being apparent.

The antennæ of the female are rather short and a little stouter than those of the male, being represented at Fig. 9 of Plate III. The scape is about one-half as long as the funicle, or one-third of the entire antenna. Joint 2 is longer and more slender than the two next following, and these—2, 3 and 4—are smooth, sparsely punctured and only thinly pubescent. Joints 5–12 are stouter and gradually increase in length, 12 being almost as long as 10 and 11 combined, and longer than any other two joints in the antenna. These joints—5 to 12—are densely punctured and pubescent, the surface sensitive and opaque, especially toward tip.

It has been stated that, after making sure that the oblique entrance was an invariable habit, casts were made directly into the perpendicular because the former was often obstructed. We found this especially in the afternoon and finally concluded that the insect used this gallery as a storehouse for sand mined during the day. It had been noted before this that the sand-heaps were all fresh each morning, new material still damp being found on every active hill. No such fresh material was seen at any time during the day, nor were the bees ever seen forcing out sand—everything of that kind was done at night. We concluded, therefore, that what the bee brought up during the day, was stored until night and then forced out through the false mouth. At times digging will cease altogether. For instance, on one occasion a

heavy rain beat all the mounds over a noted area, perfectly flat. For five days thereafter there was no external sign of work done, but after that everything went on in the usual way. The ordinary rate of progress is about five inches each day.

For several days after May 16th bees began digging in increasing numbers, and May 24th, Mr. Brakeley wrote "As for old Cock-Robin Park mine it is a sight—a horrible upheaving of the underneath—and for 20 or 30 feet all around the hole the ground looks as if it had a bad case of hives."

When the perpendicular is from 20 to 24 inches down, laterals are made and cell clusters are begun. May 22d, two casts were made. No. 1 showed a depth of 21½ inches and one cell cluster. The second was down 24 inches and had two cell clusters. This cast is fairly represented by Fig. 18 on Plate IV and it also illustrates the average system of a breeding burrow. There are rarely more than two cell clusters; but the number of cells in the clusters varies.

A section of a cell cluster containing only a single brood cell is shown at Fig. 22 (Plate IV), and many of the earliest clusters were of this type. After driving a round lateral back about an inch and a half, the insect expands it into a circular chamber, varying in diameter and in the center of this she digs a single cell somewhat barrel shaped and about three-fourth inch in depth. This cell is clay-lined on the inside and carefully smoothed down. Usually there is clay in the tube which she is digging; but if not, the bee digs out a little pocket as shown near the bottom of Fig. 18 (Plate IV), and thus obtains the material for finishing up her cradle. After this central cell is completed she digs a series of four or five around it, and of the same depth. These are not at first clay-lined but are left while the insect secures pollen to store the central cell. The pollen is formed into a round loaf, plano-convex in section, dry and firmly compacted. Upon this an egg is laid as shown in the figure. The cell is closed with a capping of clay, and the mother's work on this is done. Now the insect may either make brood cells of two or of all of the surrounding cavities or she may leave them open and unfilled. If she does the latter she deepens and curves them under the central cell until they nearly meet. In this way there is an almost continuous space all around the brood cell, only enough material being left to support the structure. If, on the other hand, she decides to turn others of these into brood cells, she enlarges the chamber accordingly

and digs other cells until the two or the five as the case may be are completely surrounded by empty cells. At Fig. 21 (Plate IV), we have a 5-cell cluster drawn from photograph which shows how such a series is arranged. The five brood cells were capped and of course the plaster could not get into them; but it did get into the surrounding air spaces, and when the cast was dug out the plaster practically inclosed the brood cells and their contents. The photograph shows that the plaster broke down and distorted the narrow partitions between the cells, two being run into one near the lateral running to the main burrow. These marginal cells had been continued beneath the brood cells, and the plaster has been trimmed away with a pen knife to expose the cells. It will be readily seen that in this way the casts preserved safely all the contents of the capped cells and we could examine the clusters at our leisure and trim out the insides whenever we wished; usually this was part of the evening's work.

The first pollen-loaded bee was seen May 24, by Mr. Brakeley. Bees were yet coming out of winter quarters and beginning new burrows on May 26th, though on the 28th some of the casts showed three cell clusters. This shows the enormous activity of the insects, the older series of which was now down from 28 to 33 inches only ten days after the real beginning of the season.

Specimens of bees taken from the new burrows May 25th, 26th and 27th reached me May 31st, and all of these were dissected. All were females and in all the ovaries showed developing ova. Usually there was a tolerably equal increase of size on both sides; but in some cases the ovary on one side was much larger than that on the other, due always to the fact that one egg was reaching maturity. The greatest development was four on one side, a single one on the other, all of about equal size. In this species there are 4 ovarian tubes, and in each tube 2 cells or eggs that seem likely to develop. It seems thus as if the insect might lay 16 eggs; but I doubt if any of them ever do place so many. The greatest number of brood cells that we ever found connected with any one cast, apparently placed by a single individual, was 15 and I much doubt whether any bee ever fills more than that. Six or seven filled cells to a single burrow is about an average, quite a number containing only two. This was not due to interference or incomplete work: such cases occurred constantly, of course; but we never counted them in our estimate. A cluster was complete when the cells surrounding the brood cell or cells were continued be-

low the latter as shown in Fig. 22, Plate IV. In such cases these surrounding spaces could never be made over into brood cells and of course the work was ended.

So far as my dissection of the bees could tell us there had been no egg-laying up to May 28th. Incidentally this examination developed uniformly, an empty alimentary tract. Apparently these insects do not feed at all after they have once begun digging and until they begin to store the cells. The mouth parts themselves are small, except for the mandibles which are shown at Fig. 10, Plate IV. The maxilla is reduced to a single-jointed, scoop-shaped galea, below which is attached a well-developed, 6-jointed palpus. The tip of this maxillary structure and the appearance of the palpus, is shown at Fig. 13, Plate III. The labium is slender and has at the tip a small pointed ligula or tongue set with rather long, fine hair along transverse ridgings or markings. The paraglossæ are small, membraneous lateral processes which do not reach the middle of the ligula and seem to be scarcely functional. The labial palpi are also small, four-jointed, the segments decreasing in size toward the tip and not set with sensory structures save a few, irregularly placed, pitted hairs. This structure is shown at Fig. 12, Plate III.

June 2d, clay-lined cells were found for the first time and now in some cases the reduced number of cell casts pointed to capped cells. But none of these were observed and it is perhaps a question whether some other causes did not interfere with the perfection of the casts.

June 4th and 5th I spent at Lahaway in the bee mines, for there were now two of them operated by Mr. Brakeley. No loaded cells were found, though quite a number were now clay-lined, apparently ready for stocking. Very few bees were observed on the wing and none of these were pollen-laden. Search among the flowers in the vicinity failed to show even a single *Augochlora humeralis*. Thousands of the insects about, yet not one feeding and not one to be obtained by ordinary collecting.

June 7th, pollen-carrying was in full swing and the bees were as active as they had been at digging shortly before. June 10th they were still hard at work, and now the direct opening to the perpendicular was in constant use, as often open as closed. Yet invariably, as soon as a pollen-laden bee entered her burrow, she reappeared in a few moments with a load of clay and closed the door. No attempt to close was made by the bee on leaving home though, theoretically,

the danger should be much greater during the mother's absence than when she is present. Practically there is nothing to prevent a parasite or predaceous species from walking right into the burrow and cleaning out the whole nest contents. No casts were made between June 5th and 11th, and there came thus an unfortunate blank.

June 11th, cast 1, poured into an open perpendicular ran down 27½ inches and had 2 cell clusters, one of six and one of five brood cells. In one of these was a pollen cake. Cast 2 had only one cell cluster. In this was one empty, clay-lined cell, and one containing a pollen cake with an egg on it. This was the first completed brood cell met with. Cast 3 had a perpendicular running down 30¾ inches. There was one cluster of three brood cells: the first was clay-lined, empty; the second had a fully completed pollen cake; the third had also an egg and was capped.

Cast 4 ran down 28 inches and had one claw cluster with three brood cells. One of these was empty, the other two were completed and with caps.

Cast 5 had two cell clusters, upper with three, lower with two brood cells and all completed with pollen, egg and cover.

June 13th, cut back along the face of one of the walls of the bee mine until a new burrow was reached and this was followed down carefully to observe the normal condition of affairs. There were two cell clusters, one at 7½, one at 8½ inches. The first contained one completed cell with pollen and egg. The second had three brood cells, one empty, one fully loaded and sealed, the third with a recently hatched larva. The empty cell had been recently clay-lined and indicated that the bee moistened the material with saliva or some other secretion. At all events the moisture penetrated to a little distance into the sand and seemed to harden it. Probably, when working in clay or a soil containing clay, this hardening mixture is all that is needed. In fact in some cases observed I feel certain that just this was done and no more.

June 15th, a number of hatched larvæ were found and then comes a break, due to the death of Mr. Brakeley's father, until June 30th, when I took up the observations myself. This makes a break during the period of development of the larva and, as pupæ were found on the 30th, there is no certainty as to the shortest period between the beginning of the larval and the pupal stage. It is certainly not over 15 days.

The pollen used to store the cells is gathered upon the middle and hind legs and upon the entire breast and base of abdomen of the insect. The middle leg is seen at Fig. 3, Plate III, and is only a little larger than the anterior; the coxa however is much more developed and the entire member is covered with hair, forming a fringe at the sides, with points inward. The femur is grooved inferiorly for the reception of the tibia. The tibia is quite a little dilated below the middle, and at the tip is a single spur with toothed edges, shown at Fig. 4 on Plate III. The claws are large and strongly toothed. The posterior leg, shown at Fig. 5, Plate III, is much longer and stronger than either of the others and also hairy throughout. In a general way the tendency is to a fringing of long, stout compound hairs directed inward to form a support to the pollen mass when gathered. There is no specialized basket as in the case of the honey bee, and this species makes no attempt to gather the collected pollen into one mass: when it flies into its burrow it is yellow where there is a hair to hold the load. The tibia has two dissimilar spurs at the tip, shown at Fig. 6, Plate III. One of these is really pectinated or comb-toothed, forming four four long dents, while the other has the edges narrowly serrated.

The first tarsal joint is longer than all the others combined, is also clothed with compound hairs and has the tip prolonged at the outer angle into a soft, curved process.

The general structure of the claws of the middle and posterior tarsi is shown at Fig. 8, Plate III. In general the claws are longer and more slender, the teeth less prominent than on the middle pair. Otherwise, and in the central structure between the claws the two pairs are alike.

Reference has been made to compound hairs. Of these there are two types in the clothing of the insect. The general covering of the functional parts of the insect is made up of palmate hairs: hairs with a flat shank, divided into from three to ten flagellæ or whips, shown at Fig. 11, Plate III. In my Annual Report for 1895, to the New Jersey Agricultural College Experiment Station, I gave on a half-tone plate, Fig. 47, a reproduction from a micro-photograph showing the compound hair of *Agepostemon* and *Augochlora*; both being of the same general type. Not all the hair is of this kind: the longer hair at the edge of the tibiæ has a straight shank with many shorter or longer branches: but it is not palmate. I have already stated that there is no specialized pollen basket and when gathering pollen the

insect simply rolls itself in the flower that the pollen may adhere to the mesh of interlacing branches of hair. This habit would seem to make it an effective pollenizer for fruits; but unfortunately no observations were made as to the kinds of flowers visited: therefore, I am unable to say at present whether the insect is of economic importance or not. I do know that the contrast between the yellow pollen and the metallic color of the insect is very striking and identifies the storing specimen at a glance.

June 30th, I made seven casts in bee mine No. 2, of which two were accidentally spoiled. All of these were made close to the point where the digging was done on the previous visit, and all were taken out the same day. In addition, I also took out a number of larvæ, pupæ, pollen cakes and eggs from the pit next to where the casts were made. The main object of this digging was to obtain specimens; but incidentally it was noted that always, in the upper cluster, there were two or three well-developed larvæ, while in the lower clusters either very young larvæ or eggs only were found. In other words, the bees, while they first complete the upper cluster before starting the lower series of cells, do not fill more than three of the upper, before they start on the lower series. The greatest number of filled cells found in any one cluster was five, and in that case three of the lower cells were also stocked.

In cast 1, I had three clusters and two branches which seemed to represent random digging. In the upper series I found one pupa and three full-grown larvæ. Neither of the lower series contained any larvæ, but the filling of some of the cells had been begun.

Cast 2 contained only an imperfect cluster and, as there was no bee in the cast, it is probable that the owner met with an accident.

Cast 3 had one partly completed cluster and one just started; but here the bee was in the cast, imbedded in one of the cells, none of which were filled. This would seem to represent a very late start or some accident that prevented work for a time.

Cast 4, extended more than four feet down. Four clusters were in whole or in part completed and three of them contained cells, either filled or in progress of being filled. All stages from the pollen cake without an egg, to the pupa were represented in this cast, but none of the outside cells had material of any kind. It was the study of this series that made the relation of the outer or air cells to the inner, brood cells, entirely clear. The bee in this instance was in the cast.

Cast 5 had three normal cell clusters and two sets of imperfect processes, one almost at the extreme bottom, nearly four feet under ground. In this cast pupæ and full-grown larvæ were found in the upper two series of cells. In the lower series pollen masses and eggs were found.

Cast 6 was a complicated affair with four cell clusters. Two bees were found in the cast and a third was taken from the mouth of the burrow before the cast was made. When cleaning out the opening preparatory to casting, a bee came up with a load of clay to close it. I removed the material, but on turning found that another load had been deposited. I waited for the next supply and captured the bee with the forceps; immediately thereafter a second bee came up; but before she could return with another load the plaster was poured in. Two bees were in the cast, a third had been captured at the entrance: what relation was there between these examples? There were four large cell clusters, one of them quite a distance from the upright, and in three of these clusters larvæ and pupæ were found. In the fourth were pollen loaves and eggs.

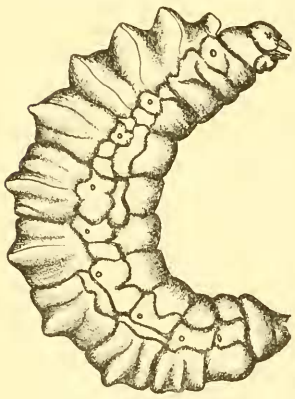

FIG. 1. Larva of *Augochlora humeralis*.

Cast 7 was the most complicated of the series, carrying four entire and two partial clusters. Four bees were imbedded in it. Larvæ and pupæ were taken out of all the clusters. One bee was imbedded in a cell cast, as if she had been engaged in filling it with pollen. The others were imbedded in different portions of the upright.

The result of the castings and diggings made it evident that on June 30, all stages from eggs to pupæ occurred in the burrows. In no pupa was there any tendency to color up, even in the eyes. The inference was that the pupa was a recent formation and that the change to the adult was at some distance off.

As to the sex of the pupæ—all of them seemed to be males. This was easily determinable by the slender form and by the prominent claspers of the genitalia which in the adult are almost completely withdrawn. I made no effort to discover sexual differences in the larvæ.

In appearance the larvæ were not in any way remarkable; they were fat, white grubs, the segments well marked, the head small, horny and yellowish. Figure 1 gives a fair representation of it. The pupa was, of course, the bundled-up adult with the sexual pieces much more prominent.

I was unable to find any reason for the presence of more than one bee in a cast unless, in some instances, two or more work in common, indicating the partial development of a social tendency. It seems reasonable to believe that those burrows that contain only two clusters with a few filled cells are made by one bee only; but it is perhaps a question whether a boring with three or more clusters is the product of a single individual in any case. Cast number 7, was evidently compound and the clusters are arranged in two series. The perpendicular extended down simply from the surface for 7 inches and was there divided into two series, each of which had cell clusters. Had there been two bees only it would have been easier to refer the matter to a common use of an entrance; but four bees require an agreement to use in common the entire perpendicular.

FIG. 2. Pupa of *Augochlora humeralis*.

There is a gap between July 1st, and July 12th–13th, when I spent another two days at Lahaway with Mr. Brakeley. On the morning of the 12th I put down twelve and Mr. Brakeley put down four casts in bee mine No. 2. In working back to these casts we found, in uncast borings, a number of cell clusters with anywhere from one to eight closed cells. All stages from the eggs to the fully colored pupæ were found, and 40 of the latter were put into closed vials for complete development; both sexes being obviously represented. A greater number of larvæ and pupæ were placed in alcohol. In general the insects were in the pupa stage. The eggs were very few and most of the larvæ were full grown.

It became increasingly evident that two or even three bees may work from the same perpendicular. Three bees were found in one cast in which there were five cell clusters. The relation of outer empty to inner filled cells, was now conclusively established by care-

ful dissection of uncast burrows. At first the insect makes one brood cell with three empties around it; rarely there are two cells in a line and four or five around it. Very occasionally there are three brood cells in a line with seven or eight empties around them. The usual form is one central with three around it, and then in order as already described. In one cast I found 10 filled cells and eleven open chambers around it.

July 13th we abandoned the regular bee mine for a study of another, higher field, which was less shaded and much hotter. Here we started another pit and, as it was a question only of cell clusters, a trench only thirty inches deep was needed. Here also we found a cluster of ten cells, all containing pupæ. A three-cell cluster was found in which was a perfectly-developed bee, capable of flight and which actually did fly a short distance in the attempt to escape. The second specimen from the same cluster was fully colored; but the wings were not yet expanded; the third was a white pupa with eyes beginning to color. This shows approximately the difference in time between the ovipositions of one bee and, from what I saw in the examples confined in the vials, there was a period of five days at least between each of these specimens. No bees of the new brood were yet about and, indeed, none of the old ones were seen above ground.

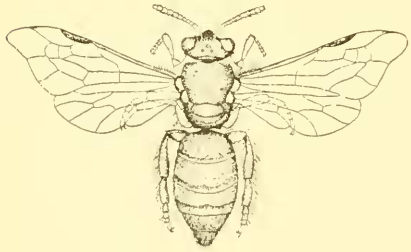

FIG. 3. Adult of *Augochlora humeralis*.

Some old bees were yet found in the burrows; but they seemed dispirited and were not at work. Many burrows had been abandoned by their makers and there was no appearance of new digging anywhere. The work of the hibernating examples was done, just about two months from the time they first began to make their appearance above ground.

Roughly then, the bees began work May 14th, the first completed cell with pollen loaf and egg was found June 11th, and the first larvæ were observed June 13th and 15th. The egg stage, then, is very brief. June 30th there were many pupæ, and a period of about fifteen days is indicated as the length of the larval life. The pupal stage is unexpectedly long, no actually emerged individuals being found on July

13th, though some were completed in the cells. This gives a full month for the pupal stage.

July 14th, Mr. Brakeley's notes are resumed, and as the result of his observations, he thinks temperature and relative maturity of the bee determine the size of the cell clusters and the number of eggs laid. Early in the season when ova are developing slowly, the bee makes only a single cell cluster, because she feels there will be plenty of time to build another series before she needs them: that series will contain from four to eight cells and form the bulk of the deposit. Late bees, coming out in hot weather, feel the ova developing too rapidly to allow of much delay and they build as many cells in one cluster as there may be need for. In case, after the main clusters are provided for, there be some late ovarian developments, a small cluster, lower down than usual is provided.

July 15th, bees were seen on the wing, and in the field where the adult was taken out of the cell July 13th, new diggers are already beginning to be notable. Whether males ever go down into these new burrows was not observed. On the 17th there were many new sand heaps, and on the 21st there was a general hatching and a general going down. Mr. Brakeley, in the course of some notes, writes: "About this time, happened to glance over the bee-bed and saw 100 blue bees or more, hovering low to the ground. Can't say where they come from, but I suspect that while I was working the upper clusters the lower series were unloading their adult bees." A sample of the conditions is shown in the following:

Case 1: Top cluster, 2 cells: 1 bee out, 1 cell yet closed, bee ready to emerge. Case 2; same status.

Case 3: Top, 2 cell cluster bees out of both; but 1 captured; lower cell cluster with larvæ.

Case 4: Top cluster, 2 bees out; lower, 1 bee out, one mature and ready to come out.

Case 5: 4 cell clusters: 1st of 10 cells, several empty, others with mature bees; 2d of 6 cells, some empty, others with bees nearly mature; 3d or 4 cells all with pupæ; 4th of one cell with larva.

July 22d, the last observation was made, and it was concluded from the fact, that digging began just as it did in May, that there would be another brood ready September 15th to 30th. So on September 17th Mr. Brakeley and myself were again on hand, making an observation trip through the blue bee territory. We saw no signs

of adults flying nor of any new burrows; but we did see signs of very recent digging from what seemed to be old sand hills. It looked as if new earth had been pushed out of the old burrows, and on investigation it proved that the oblique sand arm was being used and that bees were working in the borings. A number of the active hills were marked.

On the morning of the 18th four casts were put down, and on the afternoon three others. In digging to these casts a number of closed burrows were found and traced down with knife and trowel. An unexpected result was that not a single brood cell was found in any of the burrows; nothing but irregular fingers. The bees seem to have spent themselves in digging; first a very deep perpendicular and from that all sorts of irregular lateral galleries; but in not a single case was there a cluster of brood cells such as we found everywhere in June and July. The casts showed exactly the same features; there were a great lot of irregular processes; but there was not one single cluster, not a solitary brood cell, not a larva nor any other early stage found. And these were all burrows made by July bees! Mr. Brakeley and I saw the bees coming out of their summer burrows; and Mr. Brakeley saw them beginning to dig between July 14th and 22d. Thoughout that same territory where this digging was most active, we now find mostly flattened sand hills: a few from which fresh sand is being forced. In one case the sand was being carted directly out of the perpendicular. In the others it was forced through an oblique lateral which was not the same as that made in July: in fact, in one case we found traces of no less than three separate oblique laterals, all sand filled.

The interesting and unexpected feature was that not one of these midsummer burrows—and we traced at least twenty—showed any appearance of breeding cells. There is indeed not a particle of evidence that there has been any second brood; on the contrary, everything goes to prove that there has been none, and that the insects simply dig down to get beneath the surface: for despite their bright, metallic color they are strictly subterranean. One of the casts went down 52, another 55 inches and two of them we did not follow to the end; but where we did we usually found bees at the bottom. In other words we found practically the same condition of affairs that we found in Spring in Cock Robin Park where we first began work. Hibernation had really begun for some of them. In one case we found three bees, in another two bees, apparently working in laterals from the

same burrow: several bees then may be working in the same general system, all more or less independent of each other.

The conclusion was irresistible that there is no second brood: that the bees dig to get out of the sun and keep on digging in a sort of blind, instinctive way. They make all sorts of laterals and sometimes make processes that resemble cell clusters, in isolated instances going so far as to line individual cells with clay. But these clusters are never complete; there is never an enveloping or air space and the drop cells or fingers are of all sorts of lengths. In short the structures are not breeding cells at all. All the bees found were females, and the inference seems to be that after copulation they do more or less work all summer in a hap hazard sort of fashion; then late in the season they deepen the main burrow to between four and five feet. There from one to eight bees will pile on top of each other to go into hibernation. Some of the bees that we dug out more than four feet down, from burrows closed on top, were already almost dormant and could be freely handled without their making effort to sting; very different from the bustling activity of the newly hatched individuals or of those working on the brood cells.

The really remarkable fact is that these bees that have been digging such long burrows during the summer, abandon them in the spring and start all over again with new diggings for breeding purposes. A single bee may, in the course of its life, dig two quarter-inch tubes, which combined will equal between seven and eight feet in depth; and if the laterals and fingers can be added it would amount to at least two feet more—one of the most remarkable instances of apparently useless digging on record. Mr. Brakeley, as a matter of curiosity, weighed two bees taken in one of the winter burrows, and found them 1½ grains together; the larger of the two weighed less than one grain, and he put the problem thus: If a blue bee, weight less than one grain, will dig a hole double its own diameter, 64 inches deep, how deep ought a Princeton graduate, weight 185 pounds (or thereabouts), diameter two feet (more or less), to burrow to equal blue bee, weight for weight?

And he answers in this wise: One grain bee, 5 feet; one pound, bee, 7,000 grains—35,000 feet or, roughly, 7 miles. This would make for the Princeton graduate (or the Rutgers professor) 1,295 miles of tubing four feet in diameter! But this does not tell the whole story, for the calculation was made when we did not know that each bee digs two burrows of approximately equal depth.

Another interesting fact is this: the life of an individual female bee is eleven months at least, and of this entire period not more than ten days at the outside is passed above ground—probably much less, for only when gathering pollen does the insect come out of its den. How long an individual male lives I do not know, for circumstances prevented the continuation of observations. If it does nothing else, this note proves that an entire season may be not unprofitably spent in studying the habits of even a single species.

EXPLANATION OF PLATE III.

Structural details of *Augochlora humeralis* Patt., 1, anterior leg; antenna cleaner at *a*, at 2, yet further enlarged; 3, middle leg; 4, the single tibial spur yet further enlarged; 5, posterior leg; 6, spurs of posterior tibia, more enlarged; 7, claws of anterior tarsus; 8, claws of posterior tarsus; 9, antenna; 10, mandible; 11, palmate body hair; 12, tip of labium showing ligula, paraglossa and palpi; 13, tip of maxilla: all much enlarged. Original.

EXPLANATION OF PLATE IV.

Digging and breeding habits of *Colletes* and *Augochlora*. 14, burrow of *Colletes compacta*, the well-defined upper shaded portion representing the cast which runs to the end of the upper lateral; a "heel" extends below this lateral from the main burrow, below which the evenly shaded area represents the sand-filled portion of the digging; 15, brood cell of *C. compacta*, enlarged about two diameters, showing attachment of egg at sides, its tip resting on the food surface; 16, 17, casts made from hibernating burrows of *Augochlora humeralis*, actual length about 50 inches; 18, cast of breeding burrow of *Augochlora*, with two small cell clusters of brood cells; the oblique lateral at top, from which cast was made; lower part of cast broken off; actual length of portion shown 22 inches; 19, diagrammatic section, about ⅓ natural size, showing oblique entrance to the perpendicular burrow; sand heap at surface, the entrance to the upright closed by a plug; 20, perpendicular from which lateral extends backward, natural size; 21, cast of a cell cluster with five brood cells: 22, section through a single cell cluster about twice natural size, showing pollen loaf and egg at bottom, the outside cells continued until they almost meet below the loaded cell; 23, egg of *A. humeralis*, very greatly enlarged. Original.

EXPLANATION OF PLATE V.

Plaster cast in position in the bee mine, ready to take out: has two brood cells.

In the bee mine, showing tools and method of digging out casts and investigating burrows: each notch or angle indicates a cast taken out.